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POLYACRYLAMIDE AS A SOIL STABILIZER FOR EROSION CONTROL

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16. Abstract:

Erosion Control costs per acre on Wisconsin Department of Transportation (WisDOT) construction projects have been on the increase for the last several years. In the past, WisDOT has primarily relied on the use of expensive erosion mats to control soil erosion problems on earthen slopes and channels. This report investigates the effectiveness of using a polyacrylamide soil stabilizer. A non-toxic chain – string of organic molecules, as a soil stabilizer for controlling soil erosion on WisDOT construction projects.

The performance of polyacrylamide in controlling erosion is based on the fact that it is a flocculant. It forms ionic bonds of smaller soil particles together to make larger particles. This makes the soil more resistant to the erosive forces of dispersion and shear. Further, the polyacrylamide enhances the intrusion of water into the soil, resulting in increased soil moisture to promote seed germination, lower runoff, and less soil detachment from erosion.

Comparison of the polyacrylamide (CFM 2000, PAM) with other erosion control products that are currently used by WisDOT shows that this product is effective in controlling erosion. In addition, it is relatively inexpensive when compared to erosion mat, very easily applied, is not affected by weather conditions, and when applied following the manufacture's recommendations is environmentally safe.

17. Key Words Pavement Temperature, Weather Data, Modified Asphalts, Superpave, Reflective Cracking	
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POLYACRYLAMIDE AS A SOIL STABILIZER FOR EROSION CONTROL

A. INTRODUCTION:

Erosion control is an ever increasing cost of Wisconsin Department of Transportation (WisDOT) construction activity. A large portion of the expense in the control of erosion is the cost of materials used to keep soil in place. Until recently, WisDOT relied entirely on the use of expensive erosion mats to control the erosive forces of wind and water on bare soil. Recent advances in the field of molecular chemistry have brought about the development of low-cost polyacrylamide, PAM, a non-toxic chain-like string of organic molecules that offer a simple and inexpensive way to reduce topsoil losses from erosion. Since polyacrylamide can be obtained for about one-tenth the cost of WisDOT's Class 1, Type A erosion mats, its use could substantially reduce the cost and increase the efficiency of erosion control on WisDOT projects.

Polyacrylamide is a new generation of chemicals introduced commercially in the United States only in the last five years. The organic components of polyacrylamide were developed to chemically control erosive forces at the molecular level by holding soils in place and ionically bonding them together to increase the particle size. The result is increased water infiltration through the particle spaces and decreased erodibility of the soil particles. However, the performance of this product in controlling erosion on construction projects had not yet been established. In 1994, requests were made to the WisDOT Erosion Control and Storm Water (ECSW) committee to evaluate a polyacrylamide (CFM 2000, PAM) as a soil stabilizer for the control of erosion on construction projects. In the fall of 1996, with the cooperation of Waukesha County Airport Authority, Dane County Land Conservation, Wisconsin Department of Natural Resources, WisDOT Bureau of Aeronautics, WisDOT Bureau of Environment, WisDOT Districts 1 and 5, the WisDOT Bureau of Highway Construction Technology Advancement Unit developed a work-plan to formally test this product at different construction sites to determine if it could perform satisfactorily as a soil stabilizer.

In order for CFM 2000, PAM, to be approved as a soil stabilizer for use on WisDOT construction projects, several questions had to be answered about the product's safety and performance in controlling erosion in the field. Some of these questions are:

1) Is the product environmentally safe?
2) Does the product prevent soil loss?
3) Does the product promote or inhibit seed germination and vegetative density?
4) Is product cost effective?

The purpose of this report is to document the results of an investigation aimed at answering in detail the four questions posed above.

B. DISCUSSION:

Environmental safety as well as prevention of soil loss is of paramount importance in any erosion control product. In order for polyacrylamide to be accepted as a soil stabilizer on WisDOT projects, it must be able to meet these criteria as well as promote seed germination and maintain vegetative density. Also, the product's performance must not be hindered by either harsh environmental conditions such as cold temperature or rugged ground topography, such as steep highway embankment/cut slopes, and it must be cost effective.

To determine whether CFM 2000, PAM, has the properties mentioned above, two steps were taken :

- Its environmental safety was analyzed; and,
- A series of test plots were prepared to evaluate its performance in controlling erosion under different environmental conditions.

The research team relied on the expertise of the Wisconsin Department of Natural Resources and the Dane County Conservation Committee, as well as literature searches for the environmental safety analysis.

1. Test Sites and Product Application Procedure

WisDOT construction projects around the state were used to test the effectiveness of PAM on erosion control. The test sites included the Waukesha County Airport in the City of Waukesha, the Badger Interchange on Interstate Highway 90 in Dane County and County Trunk Highway N (a Federal Aid Project) at Black River Falls in Jackson County.

1.1 Waukesha County Airport:

The first test application of CFM 2000, PAM, on a WisDOT project was at the Waukesha County Airport in December 10, 1996. This site was composed of topsoil that was stripped and stockpiled on the southwest quadrant of the airport from a recent improvement project. The site was chosen because, not only did it meet the requirements of a disturbed soil, it also had a fairly constant slope of about 2:1 and it was isolated and away from streams and wetlands. The make up of the test plots are as shown below:

1) Plot 1: Topsoil + Polyacrylamide + Seed + Mulch
2) Plot 2: Topsoil + Polyacrylamide
3) Plot 3: Topsoil only (Control)
4) Plot 4: Topsoil + mulch + Seed

The weather condition on the day of product application was chilly, with temperatures hovering around freezing point. Due to the cold weather condition, the polymer was applied on the test plots in dry powdered form using a hand held mechanical spreader at an application rate of about 22 kg/ha (25 lbs/acre) and at an average cost of about $1250/ha ($500/acre). Product application was fast, easy and no problems were experienced in the application of the polymer.

1.2 Badger Interchange:

On July 30, 1997, a second test section was developed on the back slopes of the Badger Interchange reconstruction project at Interstate Highway 90 in Dane County. This site provided an ample opportunity to test this polymer on the same location under different temperature conditions. The site had two test application plots - one on temporary slopes with no vegetative measures, since it was not seeded, and the other on permanent slopes with topsoil that was seeded. Both test sections had a 3:1 slope. Typical layout and composition of the test plots is as shown in Figure 1 below.

Plot 1	Plot 2	Plot 3	Plot 4	Plot 5
Seed + Mulch	CFM 2000 PAM + Seed	CFM 2000 PAM + Mulch + Seed	Bare topsoil + Seed (Control)	Bare topsoil
15m (50ft)	15m (50ft)	15m (50ft)	15m (50ft)	15m (50ft)

Figure 1: Typical Layout of Test Plots.

The polymer was applied on the temporary slopes in July of 1997 and on the permanent slopes in late September of the same year. The July weather was sunny, with temperatures in the high seventies and a wind speed of about 8 km/h (5 mph). The September weather was mild also, with temperatures in the mid to high fifties. The polymer was applied to both test sites with a conventional hydroseeder. About 9 kg (20 lbs) of polymer was mixed with 7570 liters (2000 gallons) of water and seed (where applicable) in accordance with the manufacturer's specifications. This process required careful agitation of the hydroseeder to assure complete mixing of the Polymer with water. The mixed materials were applied on the slopes in three passes to achieve a 22.5 kg/ha (20 lbs/acre) uniform spread at a cost of about $1000/ha ($400/acre). The application process was efficient and without any unusual event to report.

1.3 CTH N:

CTH N at Black River Fall in Jackson County was the third test project for PAM. The site was composed of a 70 meter (225 foot) section on one side of the highway back slope that was divided into five test plots of approximately 14 meters (45 feet) each in width. All the test plots had a 2.5:1 slope, with a slope length of about 34 meters (110 feet). Other products included with polyacrylamide in this test location were seed, mulch and erosion mat. The composition of this site's test plots is as shown below:

Plot 1: Topsoil + Mulch + Seed
Plot 2: Topsoil + Class 1 Type A Erosion Mat + Seed
Plot 3: Topsoil + Polyacrylamide + Mulch + Seed

Plot 4: Topsoil +Polyacrylamide + Seed
Plot 5: Topsoil + Seed (Control)

The polymer was applied on this test site on October 22, 1997. Weather condition was typical for this time of the year in Wisconsin, cloudy with temperatures in the low forties. The polymer application procedure was the same as that of the Badger Interchange project described earlier. A conventional hydroseeder was used to achieve a 22kg/ha (20lbs/acre) uniform spread at a cost of about $1000/ha ($400/acre). Product application was easy, quick and not labor intensive.

2. Evaluation Procedure

Evaluation of the polyacrylamide CFM 2000, PAM, was based on both visual inspection and data collection made at the various test sites over a six month period. Photographs were also used to document some of the observations. The test plots were inspected periodically for evidence of:

- Riling - The number of rills were counted on each test plot and compared to that of bare soil that served as a control.
- Soil erosion - The amount of sediment collected at ends of slopes, if any, was observed and visually compared to the control at each test location.
- Seed germination and vegetative density - Three 929 cm^2 (1 ft^2) measurements of each test plot were taken: one from the upper one-third of the plot, one from the center one-third and one from the lower one-third. Plants in each measurement area section were counted and approximate plant height measured. Data obtained was compared to other test plots and the control. Each test site was monitored after application for six months at approximately one-month intervals.

C. RESULTS:

1. Environmental Effects

Environmental analysis of polyacrylamide by urban conservationist with the Dane County Land Conservation Committee, Aicardo Roa[1]. The results showed that for the rate of application required for soil stabilization as directed by the manufacturer, CFM 2000, PAM, was environmentally safe. Roa's documentation of polyacrylamide's toxicity indicated, "dry anionic PAMs that are effective in soil systems show no toxicity to fish (LC50>100 mg/l)". However, certain neutral and cationic polyacrylamides have been found to be acutely toxic at low exposure levels. The Dane County Conservation Committee also noted that the quantity of PAM, used, as a soil stabilizer was two to four times smaller than the dosage used in most food and drug products, which have been found to be safe. Since polymers are presently used in the food and drug industries, as well as the purification systems in some municipal water systems, the product was concluded to be environmentally safe.

2. Erosion Control

2.1 Waukesha County Airport Test site

Visual observations of this test site indicate that polyacrylamide made a significant reduction in the amount of erosion on the stockpiled topsoil. Although actual measurements of soil loss were not made, visual observation indicated both greater soil loss and riling on the control than on the test plot with polyacrylamide. Visual observation showed that the polymer was effective at keeping the soil from riling. Plates 1 to 4 on pages 14 and 15 show the appearance of the test plots at three weeks. There were locations on the stockpile where water was trapped at the top of the slope due to imperfections in stockpiling the material. As a result, this created rivulets that washed off more soil particles than would ordinarily occur in normal sheet flow situations after a moderate rainfall. Areas where this occurred were excluded from the test evaluation.

2.2 Badger Interchange Test Site

The weather conditions after the application of the polymer at the Badger Interchange on Interstate highway 90 test site included warm temperatures and ample light rainfall. As a result, vegetation established quickly on both the permanent and temporary slopes that were seeded with no noticeable difference in the amounts of seed germination in any of the test sections. However, on the temporary slopes, which were not seeded, there was a noticeable lack of rilling on the section that was sprayed with polymer as compared to the adjacent section that was exposed soil. Also, since this slope was so high, the hydroseeder was unable to reach the top of the slope. It was noted after three months that the top of the slope had extensive rilling, but the rills stopped when they reached the treated area. This was a significant observation on the effectiveness of this product in controlling erosion. Pictures 5 through 9 on pages 17 to 19 show seed germination and soil rilling on the different test plots on this test site.

2.3 CTH N Test Site

In addition to visual observations, data on soil erosion / rill on all five test plots were collected. This data, collected over a six-month period and shown on Table 1, page 7, indicated that Test Plot 3 (Polyacrylamide + mulch + seed) had a comparable erosion rate to Test Plot 2 (Class 1, Type A Erosion Mat + Seed) and a much lower soil erosion rate than the other remaining test plots. For example, data on the eroded soil area on the same table indicates that test plot 3 was about seven times smaller than Test Plot 1 (Mulch + Seed), five times smaller than Test Plot 4 (Polyacrylamide + Seed) and thirty-five times smaller than Test Plot 5 (Seed only), the control. The same test data is also shown graphically (Bar chart) in Figure 2.

To determine seed germination and vegetative density, plant samples were counted on a 930 cm^2 (1ft^2) section at similar locations on each test plot during different periods of the evaluation. Table 2 and 3, on pages 8 and 9, show data collected on seed germination and vegetative density respectively after a two month period on these test plots. The data describes the average number of plants per 930 cm^2 (1ft^2) for each test plot as well as the average plant height. Figures 3 and 4, on pages 8 and 9, show the same data in graphical (Bar chart) format.

Table 2 and Figure 3 indicate that Test Plot 3 (polymer + mulch + seed) had the largest seed germination rate and hence, smallest percentage of seed lost of the five test plots after a two month period. The seed germination rate on Test Plot 3 was approximately 84 percent at this same time period. This was thirty-six percent higher than that of Test Plot 4, thirty-seven percent higher than that of Test Plot 1, forty-four percent higher than that of Test Plot 5 and fifty-one percent higher that that of Test Plot 2. Test Plot 3 also had the highest vegetative density of all the test sections as shown in Table 3 and Figure 4. Photographs 10 through 14, on pages 21 through 23, show the vegetative growth and density on the different test plots after about two months.

CTH N Test Site

Table 1 Soil Erosion and Rilling data

Test Plot #	Plot composition	# of Rills	Average Rill length cm	Area of soil Eroded cm2
1	Topsoil + Mulch + Seed	17	55	935
2	Topsoil + Class 1 Type A Erosion Mat + Seed	4	20	80
3	Topsoil + polyacrylamide Mulch + Seed	6	23	138
4	Top soil + polyacrylamide + Seed	15	43	645
5	Topsoil + Seed (Control)	32	152	4864

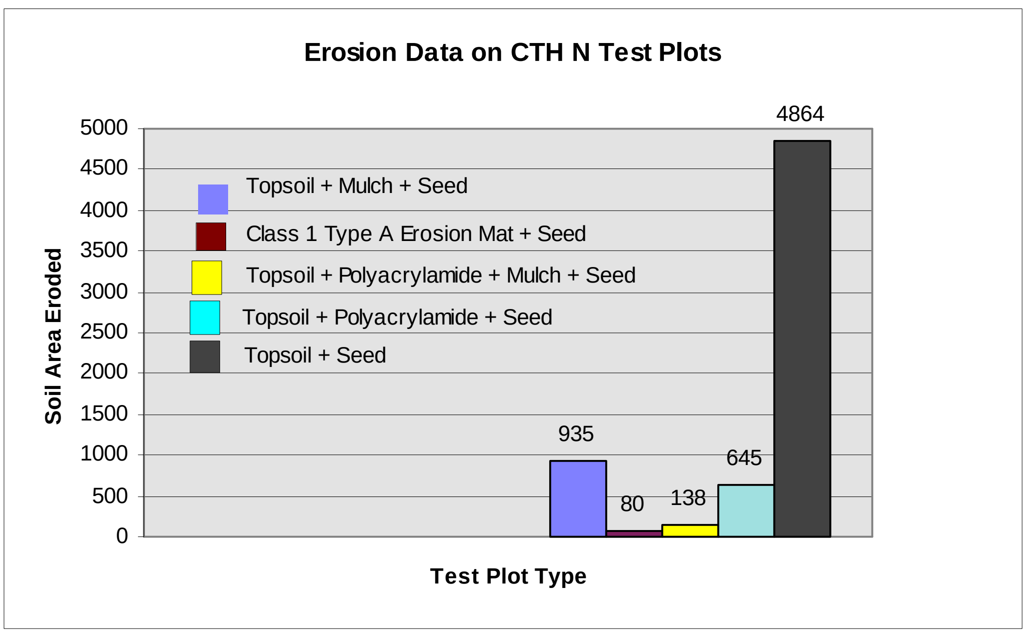


Figure 2. Bar Chart of Area of Soil Eroded.

CTH N Test Site

Table 2 Seed Germination Data

Test Plot #	Plot composition	Number of Plants Top	Middle	Bottom	Total
1	Topsoil + Mulch + Seed	63	79	93	235
2	Topsoil + Class 1 Type A Erosion Mat + Seed	58	63	42	163
3	Topsoil + polyacrylamide Mulch + Seed	142	166	154	462
4	Top soil + polyacrylamide + Seed	85	82	64	231
5	Topsoil + Seed (Control)	66	80	52	198

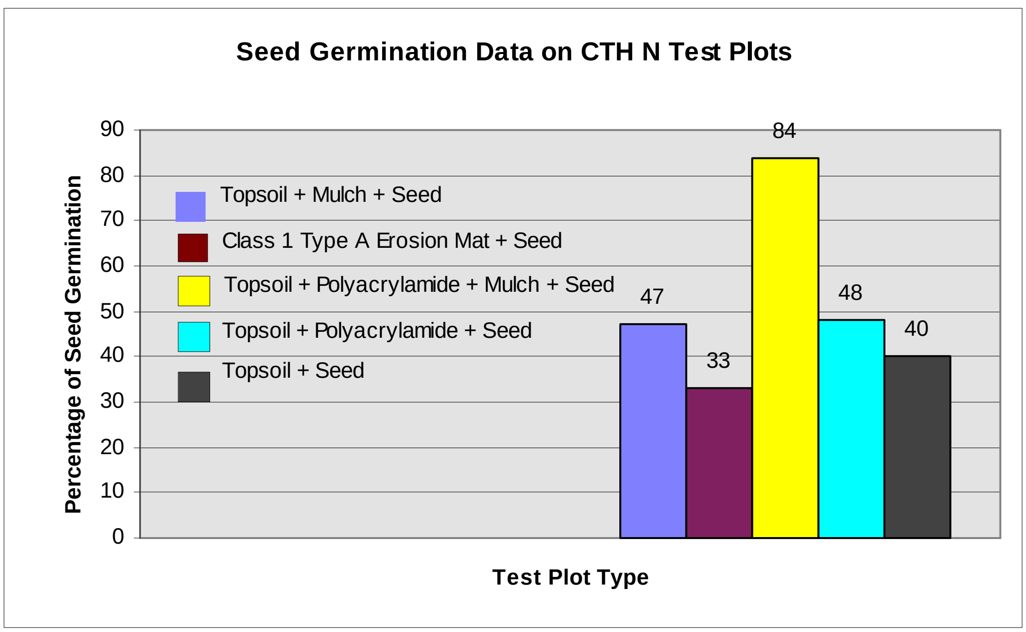


Figure 3. Bar Chart of Seed Germination.

CTH N Test Site

Table 3	Plant Height Data				
Test Plot #	Plot Composition	Plant Height (cm) Top	Middle	Bottom	Average Height (cm)
1	Topsoil + Mulch + Seed	7.5	9.0	7.5	8.0
2	Topsoil + Class 1 Type A Erosion Mat + Seed	7.5	6.3	5.0	6.3
3	Topsoil + polyacrylamide Mulch + Seed	11.4	11.4	11.4	11.4
4	Top soil + polyacrylamide + Seed	7.5	9.0	7.5	8.0
5	Topsoil + Seed (Control)	7.5	6.8	3.8	.6.0

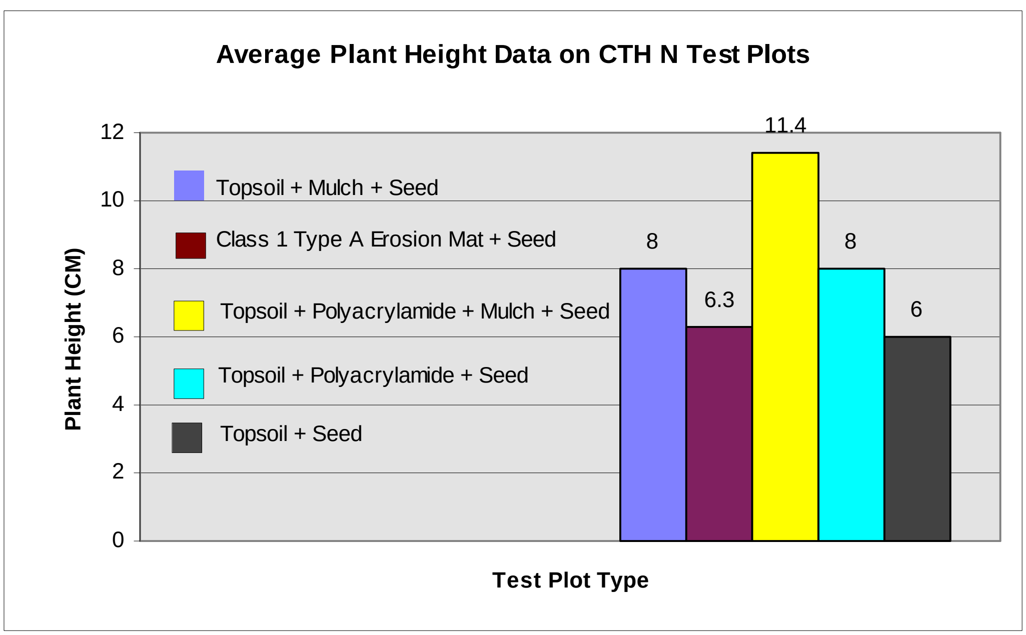


Figure 4. Bar Chart of Average Plant Height

D. CONCLUSIONS:

The following conclusions on the use of polyacrylamide CFM 2000, PAM, as an erosion control product, are based on visual observations and data collected on the various test sites during the evaluation of this product.

Comparison of CFM 2000, PAM, with other erosion control products that are currently used by WisDOT, shows that this product is effective in controlling erosion, is easily applied, and at a material and installation cost of approximate $1250/ha ($500/acre), is relatively inexpensive when compared to the $11,250/ha ($4,500/acre) for WisDOT Class 1 Type A, erosion mats. Also, when the manufacture's recommended application rate is followed, the product is environmentally safe.

The performance of CFM 2000, PAM, in controlling erosion is based on the fact that it binds soil together into particles of a larger size. This makes the soil more resistant to collapse, dispersion and shear forces. Soil infiltration rates also appear to increase with the use of PAM. This results in more available water for the seeds to germinate, lower runoff and less soil detachment from erosion.

CFM 2000, PAM, performed comparably to erosion mat and better than mulch and seed on slopes of 2:1 or less in controlling erosion prior to the establishment of permanent vegetation. The combinations of the Polymer, seed and mulch performed the best for erosion control and vegetative growth.

From the data of Table 1 on the CTH N test plots and its graphical representation in Figure 2, it follows that Test Plot 2 (Class 1 Type A erosion mat plus seed) and Test Plot 3 (polyacrylamide, mulch, and seed) produced the smallest amounts of eroded soil of all five test sections after six months of observation. Initial indications also showed that, not only did Test Plot 3 produce the most seed germination and the densest vegetation, it also produced the tallest grass plants. Although field observations eight months after the products were placed showed no significant difference in plant height, the test plot with polyacrylamide, mulch and seed appeared to have the denser vegetation.

E. RECOMMENDATIONS:

It is the recommendation of this report that CFM 2000, PAM, and other polyacrylamides with the same specifications, be accepted for use as a soil stabilizer on WisDOT construction projects for both temporary and permanent erosion control applications. The following are guidelines for the use of PAM.

1. When protection of slopes and embankments is required, a combination of polyacrylamide, mulch and seed is recommended. This may be especially beneficial in helping to establish vegetation on the slopes in late fall when weather conditions make it difficult to establish vegetation on the project.

2. The manufacturer's recommended application rate and procedure should be strictly adhered to and the product should not be applied near streams. When the product is applied in liquid form, agitation of the water in the hydroseeder tank is recommended to properly mix the PAM. Otherwise, the product may not completely dissolve. The undissolved PAM may clog the equipment or end up as thick ooze on the applied surface.

3. CFM 2000,PAM, should be approved and placed in the appropriate soil stabilizer class category in the WisDOT Erosion Control Product Acceptability List, (PAL) . This approval will remain valid as long as the product meets the specifications and performs satisfactorily in the field.

E. Implementation:

1. Wisconsin's Erosion Control Product Acceptability List (PAL) will show modifications with the addition of a soil stabilizer Type B.

2. CFM 2000, PAM will be added to the PAL as an approved Type B soil stabilizer.

3. Specific testing protocol will be developed for future testing of Type B soil stabilizers.

REFERENCES:

1. **Aicardo**, Roa.; "Polyacrylamide for Enhancing Sediment and Pollutant Removal in Urban Catchment Basins." Dane County Land Conservation, July 1997.

2. **Vydrzal**, R., and D. Okpala. "Polyacrylamide CFM 2000 PAM as a Soil Stabilizer for Erosion Control." New product Evaluation, Interim Report. Research Study # 97-06, Report # WI-09-97, August 1, 1997.

APPENDIX A:

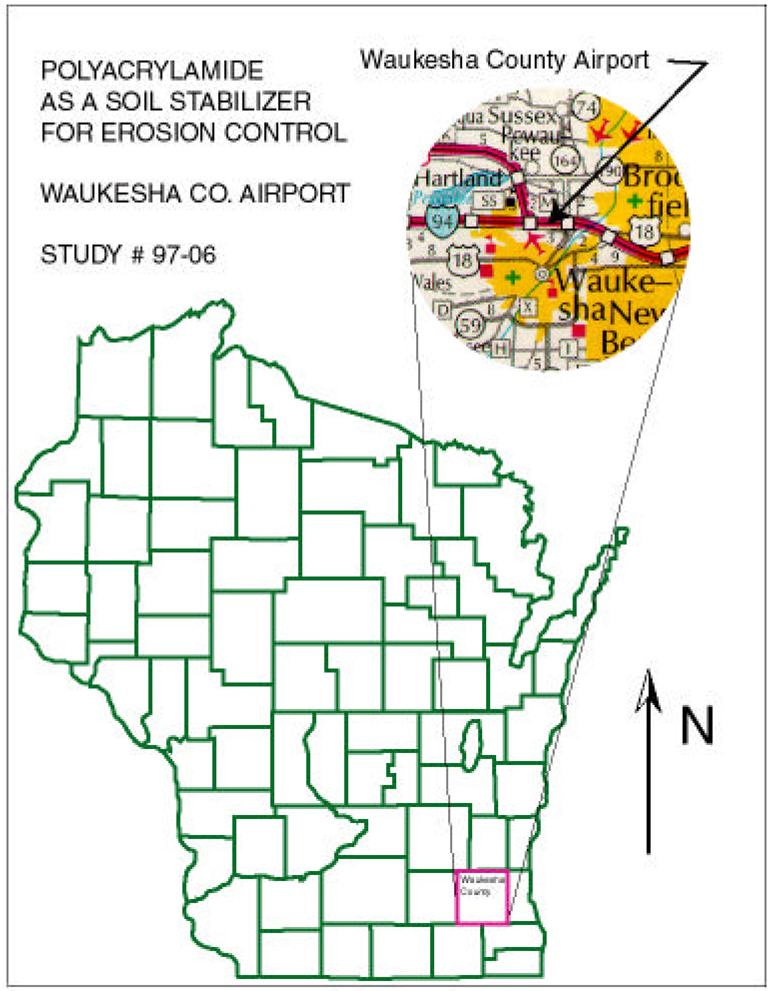
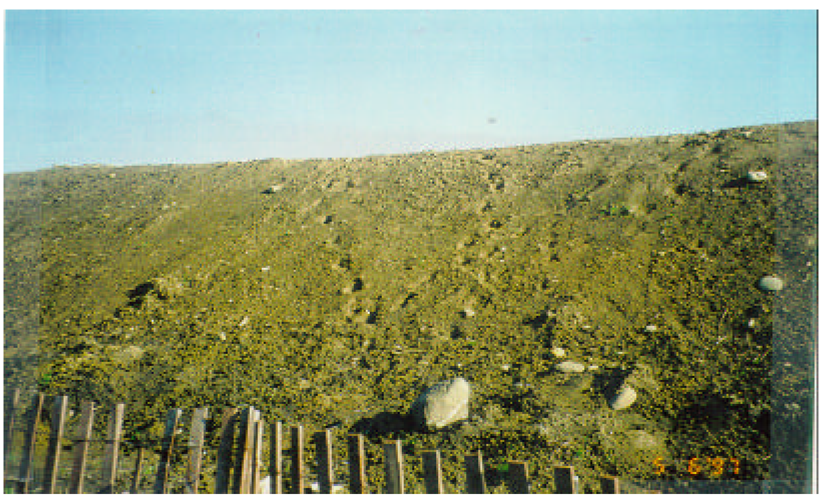


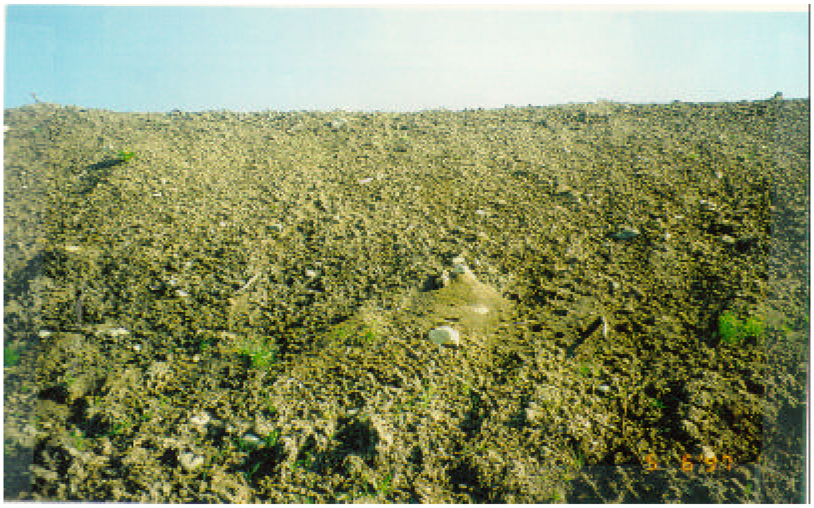
Figure 5. Location of the Waukesha County Airport Test Site

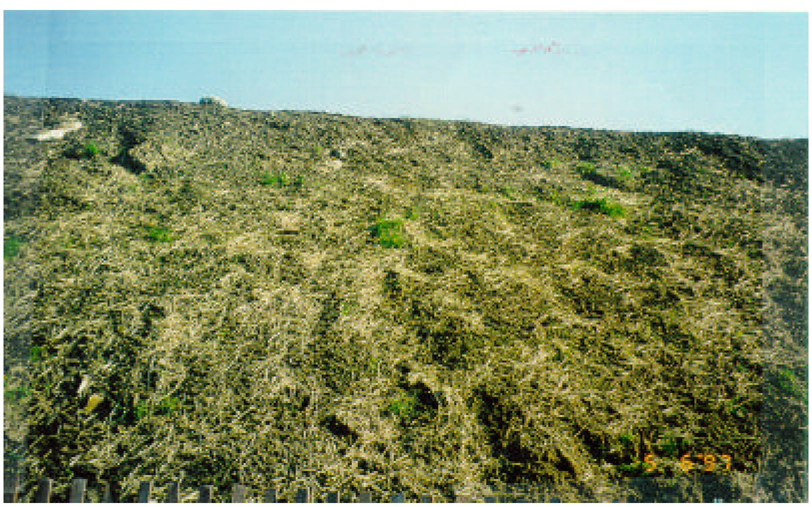
Pictures 1 through 4 show the different test plots on the Waukesha Airport test site at three weeks.

Picture 1: Topsoil + Polyacrylamide + Seed + Mulch



Picture 2: Topsoil + Polyacrylamide


Picture 3: Topsoil as Control


Picture 4: Topsoil + Seed + mulch

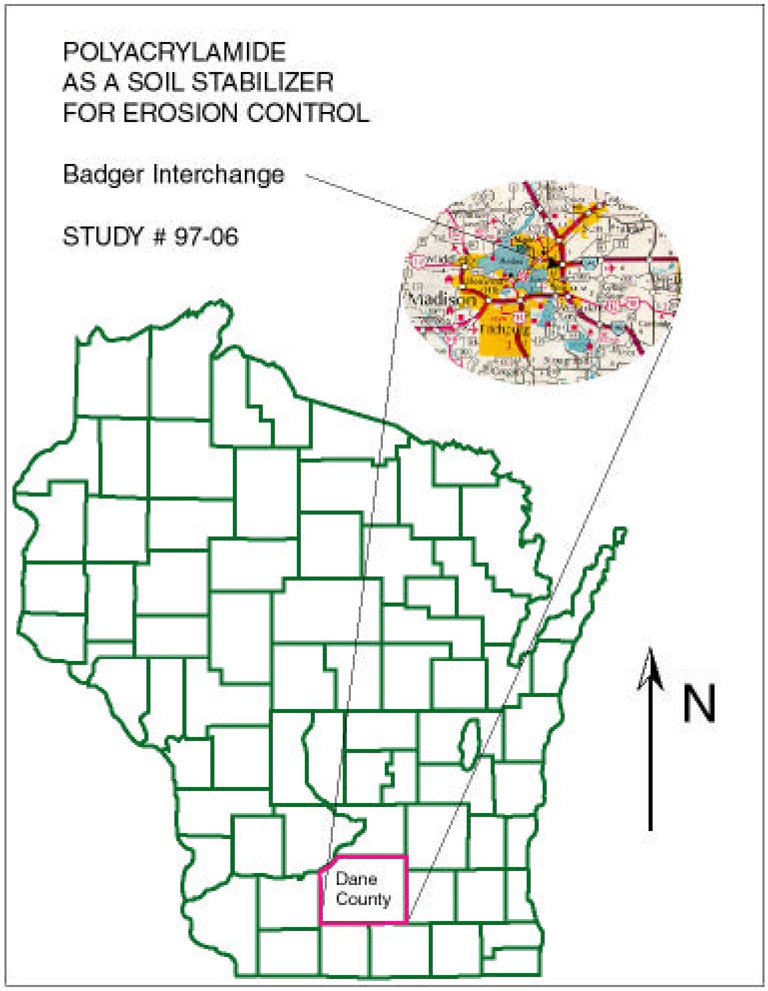


Figure 6. Location of the Badger Interchange Test Site

Pictures 5 through 9 show seed germination/soil riling on the permanent slopes of the Badger Interchange test site after two months.

Picture 5: Topsoil + Mulch + Seed

Picture 6: Topsoil + Polyacrylamide + Seed

Picture 7: Topsoil + Seed

Picture 8: Topsoil + Polyacrylamide + Mulch + Seed

Picture 9: Topsoil + Class 1 Type A Mat + Seed

Figure 7. Location of the CTH N Test Site

Picture 10 through 14 show seed germination and vegetative density on the CTH N test site after about two months.

Picture 10: Topsoil + Mulch + Seed

Picture 11: Topsoil + Class 1, Type A Mat + Seed

Picture 12: Topsoil + Polyacrylamide + Mulch + Seed

Picture 13: Topsoil + Polyacrylamide + Seed

Picture 14: Topsoil + Seed (Control)